

ment in the upper levels. In the eastern and central portions of the United States this relation appears to be closest for cyclones at about 3 to 3½ kilometers and for anticyclones at about 1½ to 2 kilometers, somewhat higher in each case in summer than in winter. These are averages; in individual cases there are wide variations, owing chiefly to variations in temperature distribution, both horizontal and vertical. What is needed is an accurate representation of free-air pressures, and therefore winds, at different levels up to about 5 kilometers; in other words a series of synoptic maps for these levels similar and supplemental to the one regularly used for the sea level plane. It was to this problem that Doctor Meisinger applied his fine training and talents, and it was in an effort to secure additional data for its better understanding that he gave his life. He realized fully that he had made a beginning only, but he also believed, and many of us have the same conviction, that he was on the right track. Material modification would undoubtedly have to be made in details (Doctor Meisinger himself expected this), but the purpose and much of the general plan are undoubtedly sound. The purpose was not to have these free-air pressure maps take the place of actual observations, but to supplement them, since the latter can not always be made, at any rate with methods at present

employed. This problem then is presented as the most important now before us—one demanding talents and training of the highest order.

*Summary.*—There are of course innumerable other problems awaiting our attention, but the emphasis in this paper is placed upon the word "outstanding." Of those presented there are seven for which data are already available, in part at least, viz, diurnal variation; winds and weather along airways; the free air in thunderstorms; in clouds; in the Tropics; and in cyclones and anticyclones; and the application of free-air data to forecasting. Studies along these lines have been and are being made but the field is wide open. The problems are especially recommended to graduate students who aspire to compete for grants from the Meisinger Aerological Research Fund. The purpose of that fund, as stated, is "the promotion of aerological research, \* \* \* to the end that the type of research in which Doctor Meisinger was engaged shall be encouraged," and all of these problems meet that specification. Later, when the necessary data shall have been secured, the other two problems, viz, the free air in the polar regions and the stratosphere, will in their turn provide opportunity for researches which can hardly fail to yield results of far-reaching value in theoretical and applied meteorology.

#### AVERAGE FREE-AIR WINDS AT LANSING, MICH.

By C. L. RAY

[Weather Bureau Office, Lansing, Mich., January, 1925]

At the end of May, 1924, the pilot-balloon flights at the Lansing station had reached a total of approximately 2,100, covering a period of five years, June, 1919, to May, 1924, inclusive. These data have been summarized and the results are presented in this paper, which is, in some respects, a revision of an earlier paper of the same title,<sup>1</sup> although additional features, such as resultant winds, and a classification according to surface direction, are now included. The observations have in all cases been made with one theodolite, and the data are therefore subject to the errors of that method. From numerous two-theodolite observations it has been shown, however, that these errors are as a rule not large and that they are quite negligible when mean values are considered, as in the present paper.<sup>2</sup> Until August 1, 1921, two observations were made daily, at 7 a. m. and 3 p. m.; since that time there has been one only each day, that of the afternoon.

Lansing is located about midway between Lakes Michigan and Erie. Its geographic coordinates are: Altitude, 263 m.; latitude, 42° 44' N; and longitude, 84° 26' W. It lies close to the tracks of most of the cyclones that cross the country, with the exception of those that come up the Atlantic coast. The large percentage of days with precipitation or at least cloudiness and with strong winds, associated with these storms, renders the location unfavorable for the best results, so far as continuity of record and the attainment of a high average altitude are concerned. Nevertheless, the records of the period show that the loss of flights for all seasons is only 12 per cent. A maximum of 20 per cent reached during the winter months is balanced by a minimum of less than 5 per cent during the summer, while the spring and autumn show a failure to secure flights 11 per cent of the time.

Table 1 contains the seasonal and annual totals of all flights made during the five-year period. This total of more than 2,100 flights offers a satisfactory basis for the computation of average values. In the upper levels the number of flights available becomes smaller, as different things occur to terminate the individual ascensions. However, there are 1,007 observations at 3,000 meters, 682 at 4,000 meters, 489 at 5,000 meters, and 341 at 6,000 meters. At higher levels observations are too few to give dependable means. In all cases heights are given above the surface.

TABLE 1.—Number of pilot-balloon ascensions, at Lansing, Mich.

Altitude (meters)	Spring	Summer	Autumn	Winter	Annual
250.....	532	604	534	454	2,124
500.....	507	598	518	405	2,028
750.....	481	583	484	343	1,891
1,000.....	458	573	439	308	1,778
1,500.....	396	529	381	247	1,553
2,000.....	349	457	339	209	1,354
2,500.....	293	398	277	185	1,153
3,000.....	251	355	241	160	1,007
3,500.....	206	285	193	124	806
4,000.....	169	265	157	105	696
4,500.....	148	233	120	72	573
5,000.....	123	212	103	54	492
6,000.....	81	156	68	36	341

In Tables 2 and 3 are shown, respectively, the number of flights with differing surface directions and the percentage-frequency of winds from the various points of the compass. The percentage-frequency of winds from different directions at the surface and at 2 and 6 kilometers for the summer, the winter, and the year is also shown in Figure 1. It will be noted that during the spring months 45 per cent of the surface winds have a south component, during the summer 47 per cent, in the autumn 53 per cent, and in the winter 47 per cent. North surface components are observed 43 per cent of the time in the spring, 40 per cent in the summer, 30 per

<sup>1</sup> MO. WEATHER REV., December, 1922, 50: 642-645.

<sup>2</sup> Haines, W. C., Ascensional Rate of Pilot Balloons. MO. WEATHER REV., May, 1924, 52: 249-253.

cent in the autumn, and 36 per cent in the winter. At 4,000 meters 24 per cent of the winds are marked by a south component in the spring period, 18 per cent in the summer, 34 per cent in the autumn, and 16 per cent in

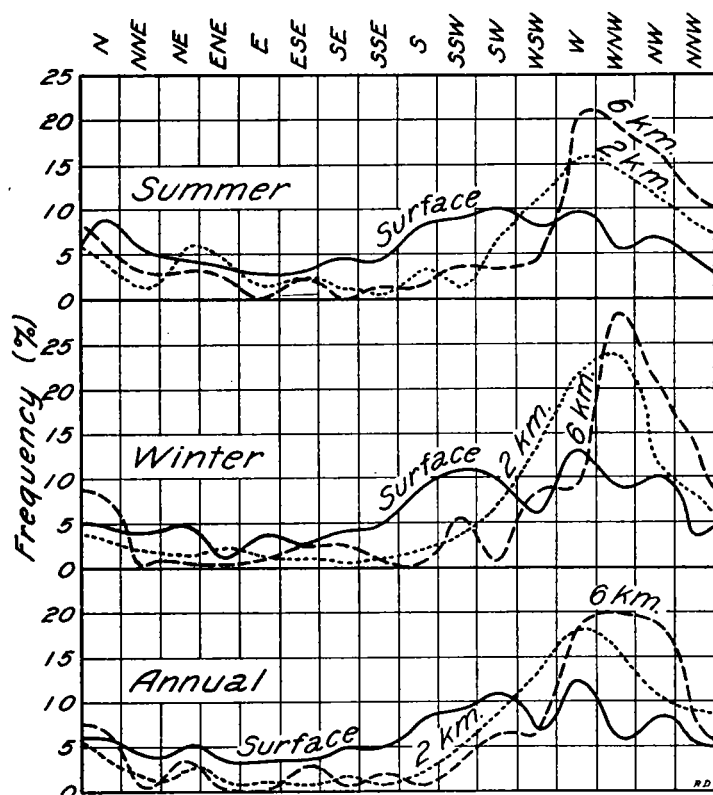


FIG. 1.—Percentage frequency of winds from different directions at the surface, 2 and 6 kilometers, at Lansing, Mich.

the winter. A north component is observed 56 per cent of the time during the spring months at the 4-kilometer level, 66 per cent in the summer, 43 per cent in the autumn, and 56 per cent in the winter.

TABLE 2.—Number of flights with different surface directions at Lansing, Mich.

SPRING																
Altitude m.	n.	nne.	ne.	ene.	e.	ese.	se.	sse.	s.	ssw.	sw.	ws.	w.	wnw.	nw.	nnw.
250	29	24	36	22	22	14	26	26	45	43	48	32	47	46	40	20
500	20	14	35	21	12	20	15	18	42	58	45	62	40	40	40	27
750	16	17	25	25	20	16	16	14	13	34	60	44	60	40	46	23
1,000	18	21	15	18	19	13	13	10	10	25	60	47	64	34	50	29
2,000	24	12	14	6	8	10	5	6	4	17	36	39	52	37	39	28
3,000	15	15	7	4	6	1	4	5	5	9	19	23	43	22	44	18
4,000	10	6	4	3	4	2	2	5	2	6	9	12	31	21	28	16
5,000	6	5	4	1	1	4	4	0	3	6	4	10	18	22	19	12

SUMMER																
Altitude m.	n.	nne.	ne.	ene.	e.	ese.	se.	sse.	s.	ssw.	sw.	ws.	w.	wnw.	nw.	nnw.
250	37	48	24	23	19	20	16	29	33	30	52	64	60	50	45	30
500	34	40	36	19	20	21	21	17	32	27	49	68	64	56	50	30
750	40	29	37	21	13	20	15	23	29	21	49	57	76	61	47	32
1,000	39	25	36	13	24	13	13	16	22	30	37	58	81	72	44	37
2,000	33	8	25	15	8	11	7	7	12	8	30	53	68	71	54	35
3,000	19	7	19	4	5	8	6	4	1	8	19	45	50	59	56	35
4,000	13	11	10	5	2	2	4	4	3	4	12	20	39	69	41	18
5,000	13	8	6	7	2	2	2	1	5	2	6	18	34	45	36	17

TABLE 2.—Number of flights with different surface directions at Lansing, Mich.—Continued

AUTUMN																
Altitude m.	n.	nne.	ne.	ene.	e.	ese.	se.	sse.	s.	ssw.	sw.	ws.	w.	wnw.	nw.	nnw.
250	23	19	17	14	14	19	25	30	37	54	73	39	75	28	36	24
500	19	15	19	8	12	7	18	26	22	44	57	71	67	54	45	27
750	19	11	7	8	12	6	14	17	29	39	55	59	82	46	47	27
1,000	17	10	4	6	8	4	8	12	29	31	58	50	84	40	50	23
2,000	16	3	5	4	2	0	5	6	9	19	34	51	70	54	34	22
3,000	9	8	2	0	2	0	1	3	10	10	16	35	51	42	34	16
4,000	4	3	1	1	3	0	1	1	3	6	17	21	30	24	30	10
5,000	7	2	2	0	1	0	1	1	5	4	4	13	23	18	15	5

WINTER																
Altitude m.	n.	nne.	ne.	ene.	e.	ese.	se.	sse.	s.	ssw.	sw.	ws.	w.	wnw.	nw.	nnw.
250	17	17	17	12	12	15	12	14	26	36	44	45	63	48	42	23
500	17	15	12	7	10	13	9	10	24	15	39	56	61	50	36	20
750	19	4	6	5	13	5	9	8	10	19	24	52	52	46	42	18
1,000	11	7	8	3	9	6	3	8	8	12	23	41	58	39	46	15
2,000	6	3	2	4	2	2	1	0	2	6	10	29	46	45	24	17
3,000	6	2	3	2	1	3	1	0	0	3	8	13	42	33	25	10
4,000	7	1	1	2	1	0	0	0	1	2	7	6	27	22	18	5
5,000	5	0	0	2	1	0	0	0	0	1	2	3	11	8	9	7

ANNUAL																
Altitude m.	n.	nne.	ne.	ene.	e.	ese.	se.	sse.	s.	ssw.	sw.	ws.	w.	wnw.	nw.	nnw.
250	106	108	104	71	67	68	79	99	141	163	217	180	245	172	163	97
500	90	84	102	60	63	53	68	68	96	128	203	240	254	200	171	104
750	94	61	75	59	58	47	54	62	81	113	188	212	270	193	182	100
1,000	85	63	63	40	60	36	37	46	69	98	178	196	287	185	190	104
2,000	79	26	46	29	20	23	18	19	27	50	110	172	236	207	151	102
3,000	49	32	31	10	14	12	12	12	16	30	62	116	186	156	150	79
4,000	34	21	16	11	10	4	7	10	9	18	45	59	127	136	117	40
5,000	31	15	12	10	5	6	7	2	13	13	16	44	86	93	79	41

TABLE 3.—Percentage frequency of winds observed from various directions at Lansing, Mich.

SPRING																
Altitude m.	n.	nne.	ne.	ene.	e.	ese.	se.	sse.	s.	ssw.	sw.	ws.	w.	wnw.	nw.	nnw.
Surface	6	5	7	5	4	3	5	5	10	8	8	6	8	8	8	4
1,000	4	5	4	6	4	2	3	3	2	5	13	11	13	8	11	6
2,000	7	4	3	2	2	3	2	2	1	6	11	11	15	11	11	9
4,000	7	4	2	2	2	1	3	1	6	5	8	18	13	17	11	5
6,000	5	2	8	0	2	2	2	1	4	0	11	2	16	20	20	5

SUMMER																
Altitude m.	n.	nne.	ne.	ene.	e.	ese.	se.	sse.	s.	ssw.	sw.	ws.	w.	wnw.	nw.	nnw.
Surface	9	6	5	4	3	3	5	4	8	9	10	8	10	5	7	4
1,000	7	5	6	2	4	2	2	3	4	5	7	10	15	13	8	7
2,000	7	2	6	4	2	3	1	1	3	2	7	11	16	15	12	8
4,000	5	5	4	2	1	1	1	1	1	1	5	8	15	27	15	8
6,000	7	3	3	3	0	3	0	1	1	3	3	4	21	19	17	12

AUTUMN																
Altitude m.	n.	nne.	ne.	ene.	e.	ese.	se.	sse.	s.	ssw.	sw.	ws.	w.	wnw.	nw.	nnw.
Surface	4	3	3	3	3	4	5	6	7	10	14	7	14	5	7	5
1,000	4	2	1	1	2	1	2	3	6	7	13	13	19	9	12	5
2,000	5	1	2	1	1	0	2	2	3	5	10	15	20	17	10	6
4,000	2	1	1	1	2	0	1	1	2	4	11	15	19	15	18	7
6,000	9	3	4	0	0	1	0	0	1	3	4	12	24	18	17	4

WINTER																
Altitude m.	n.	nne.	ne.	ene.	e.	ese.	se.	sse.	s.	ssw.	sw.	ws.	w.	wnw.	nw.	nnw.
Surface	5	4	5	1	4	3	4	5	8	11	10	6	13	8	10	3
1,000	4	3	3	1	4	2	1	3	3	4	8	13	18	13	15	5
2,000	3	2	0	2	1	1	0	0	1	3	7	13	22	24	12	9
4,000	7	1	1	2	1	0	0	0	1	2	7	6	27	21	18	6
6,000	8	0	0	0	0	3	3	0	0	6	0	8	8	28	22	14

ANNUAL																
Altitude m.	n.	nne.	ne.	ene.	e.	ese.	se.	sse.	s.	ssw.	sw.	ws.	w.	wnw.	nw.	nnw.
Surface	5	5	5	3	3	3	4	5	7	8	10	9	12	8	8	5
1,000	5	4	4	2	3	2	2	3	4	6	10	11	16	11	11	6
2,000	6	2	4	2	2	2	1	1	2	4	8	13	18	16	11	8
4,000	5	3	2	2	1	1	1	1	1	3	7	9	19	20	18	7
6,000	7	3	2	2	1	1	2	0	3	3	3	9	18	20	17	9

In Table 4 and Figure 2 the mean free-air wind directions and velocities are given by seasons. It will be seen that at the surface the winds are between southwest and west and that the southerly influence is most pronounced in the autumn period. Above the surface there is on the average a gradual clockwise turning of the wind. During the autumn months a persistent westerly wind is to be observed up to 4,000 meters with a slight shift to WNW. above this height. In other seasons the north component is evident, beginning at about 2,000 meters, and the northwest trend becomes more strongly marked as the higher levels are reached.

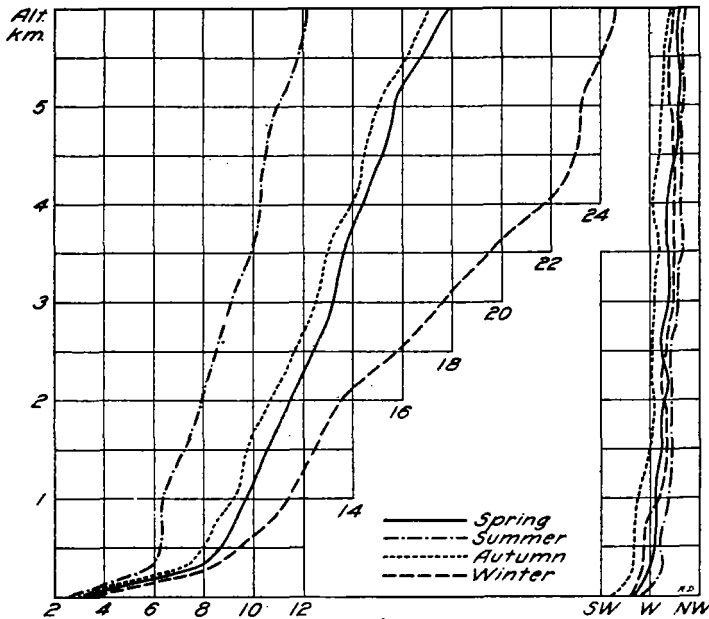


FIG. 2.—Mean seasonal free-air wind directions and speeds, m. p. s., at Lansing, Mich.

TABLE 4.—Mean free-air winds at Lansing, Mich.

Altitude	Spring		Summer		Autumn		Winter		Annual	
	Direction	Vel.	Direction	Vel.	Direction	Vel.	Direction	Vel.	Direction	Vel.
m.		m. p.		m. p.		m. p.		m. p.		m. p.
Surface	S. 75°W.	3.7	S. 85°W.	2.3	S. 61°W.	2.8	S. 74°W.	3.4	S. 74°W.	3.1
250	S. 87°W.	7.9	N. 78°W.	5.7	S. 75°W.	7.3	S. 84°W.	8.0	S. 87°W.	7.2
500	S. 88°W.	9.0	N. 78°W.	6.2	S. 80°W.	8.0	W	9.7	W	8.2
750	S. 88°W.	9.5	N. 74°W.	6.2	S. 79°W.	8.4	N. 84°W.	10.9	N. 88°W.	8.8
1,000	N. 79°W.	9.8	N. 72°W.	6.3	S. 82°W.	9.3	N. 81°W.	11.2	N. 82°W.	9.2
1,500	N. 74°W.	10.6	N. 71°W.	7.2	N. 89°W.	9.8	N. 75°W.	12.4	N. 77°W.	10.0
2,000	N. 75°W.	11.5	N. 67°W.	7.8	N. 85°W.	10.7	N. 74°W.	13.5	N. 75°W.	10.9
2,500	N. 74°W.	12.6	N. 68°W.	8.4	N. 84°W.	11.7	N. 74°W.	15.9	N. 75°W.	12.2
3,000	N. 65°W.	13.1	N. 65°W.	9.0	N. 82°W.	12.5	N. 69°W.	17.6	N. 70°W.	13.0
3,500	N. 67°W.	13.7	N. 60°W.	9.9	N. 81°W.	13.1	N. 70°W.	19.5	N. 70°W.	14.0
4,000	N. 67°W.	14.4	N. 61°W.	10.1	N. 82°W.	14.1	N. 60°W.	21.8	N. 70°W.	15.1
4,500	N. 64°W.	15.2	N. 60°W.	10.4	N. 77°W.	14.6	N. 61°W.	22.9	N. 66°W.	15.8
5,000	N. 68°W.	15.6	N. 60°W.	11.2	N. 72°W.	15.2	N. 57°W.	23.1	N. 64°W.	16.3
6,000	N. 66°W.	16.0	N. 58°W.	12.3	N. 67°W.	17.3	N. 57°W.	24.9	N. 62°W.	17.6

The average surface wind velocity is 3 meters per second, being slightly greater during the spring and winter and least in the summer. With increase of altitude the distinguishing features are the low summer and high winter averages, the latter reaching gale force at 3,000 meters. Spring and autumn velocities are somewhat less than those of winter but attain gale force at 6,000 meters.

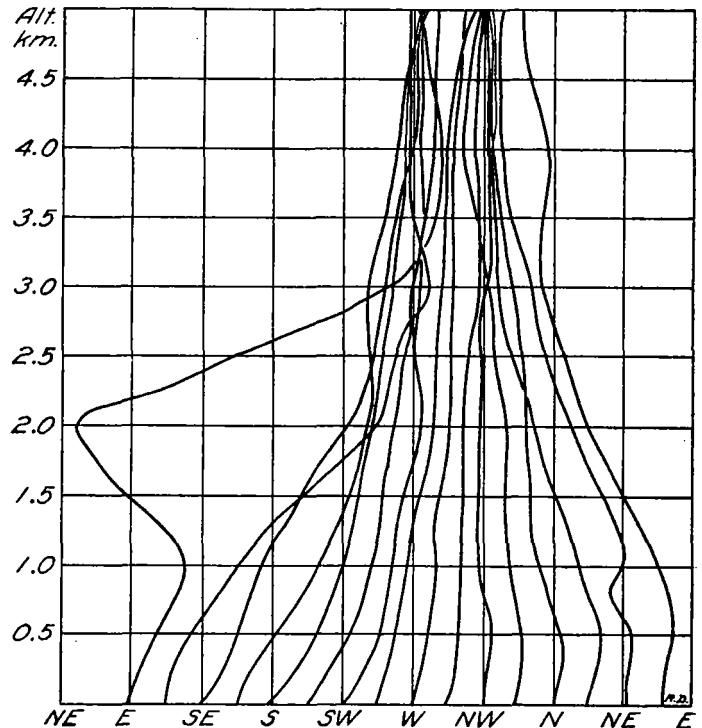


FIG. 3.—Mean annual free-air wind directions as related to surface directions at Lansing, Mich.

In Table 5 and Figure 3 are presented the wind averages grouped by the different surface directions. These show a turning of the north component winds to the left and of south component winds to the right, while east surface winds become somewhat variable with increase of altitude. These turnings continue until at the higher levels there is to be noted a grouping of the directions entirely between north and west. The velocities for all directions increase at about the same rate to the 500-meter level, above which west winds continue to increase in velocity while east winds decrease, with altitude, at the same time shifting to westerly. At 3,000 meters the mean direction of the winds, whatever the direction at the surface, is between WSW. and NNW., while at 5,000 meters the directions are limited by W. and NNW.

TABLE 5.—Average direction and speed of free-air winds at Lansing, Mich., for different directions at the surface  
SPRING

Surface		Altitude (meters)															
		250		500		750		1,000		2,000		3,000		4,000		5,000	
Direction	Velocity (m. p. s.)	Direction	Velocity (m. p. s.)	Direction	Velocity (m. p. s.)	Direction	Velocity (m. p. s.)	Direction	Velocity (m. p. s.)	Direction	Velocity (m. p. s.)	Direction	Velocity (m. p. s.)	Direction	Velocity (m. p. s.)	Direction	Velocity (m. p. s.)
N	3.0	N. 5°W.	5.1	N. 10°W.	5.7	N. 21°W.	6.4	N. 16°W.	7.1	N. 19°W.	9.0	N. 23°W.	11.5	N. 41°W.	13.2	N. 46°W.	13.2
NNE	3.6	N. 30°E.	6.0	N. 37°E.	6.9	N. 33°E.	8.1	N. 21°E.	8.6	N. 5°E.	7.8	N. 17°W.	9.8	N. 41°W.	11.9	N. 40°W.	14.9
NE	3.4	N. 55°E.	7.5	N. 53°E.	8.2	N. 56°E.	8.3	N. 53°E.	8.4	N. 26°E.	8.3	N. 13°W.	9.8	N. 27°W.	11.6	N. 39°W.	13.6
ENE	3.1	N. 69°E.	6.8	N. 75°E.	6.8	N. 79°E.	6.6	N. 76°E.	6.6	N. 29°W.	7.7	N. 18°W.	8.5	N. 20°W.	9.6	N. 32°E.	10.8
E	3.6	S. 58°E.	7.4	N. 88°E.	8.1	S. 85°E.	8.2	S. 73°E.	7.8	S. 73°E.	6.5	N. 19°W.	5.5	N. 26°E.	6.6	S. 71°W.	9.5
ESE	3.1	S. 70°E.	6.6	S. 55°E.	7.5	S. 47°E.	7.1	S. 39°E.	7.0	S. 16°E.	8.1	S. 41°W.	8.4	S. 48°W.	9.4	S. 46°W.	10.4
SE	3.2	S. 40°E.	7.4	S. 33°E.	9.0	S. 29°E.	9.6	S. 29°E.	9.1	S. 36°W.	8.7	S. 50°W.	11.1	N. 67°W.	12.2	S. 80°W.	14.0
SSE	4.0	S. 15°E.	8.8	S. 13°W.	10.7	S. 13°W.	10.6	S. 29°W.	10.5	S. 74°W.	10.7	S. 76°W.	10.4	S. 79°W.	12.2	S. 82°W.	12.8
S	3.7	S. 18°W.	8.9	S. 28°W.	10.9	S. 34°W.	11.0	S. 41°W.	11.3	S. 58°W.	11.1	S. 73°W.	13.8	S. 68°W.	15.3	S. 74°W.	17.2
SSW	4.0	S. 40°W.	10.9	S. 44°W.	12.6	S. 51°W.	12.9	S. 58°W.	12.9	S. 71°W.	16.5	S. 83°W.	18.5	N. 83°W.	20.7	N. 78°W.	22.6
SW	3.7	S. 56°W.	9.0	S. 58°W.	10.6	S. 60°W.	10.9	S. 62°W.	11.2	S. 68°W.	13.0	S. 77°W.	13.9	S. 73°W.	15.8	S. 79°W.	17.2
WSW	4.0	S. 77°W.	10.0	S. 81°W.	11.0	S. 83°W.	12.3	S. 87°W.	11.3	N. 76°W.	15.9	N. 84°W.	17.7	N. 54°W.	19.5	N. 30°W.	20.4
W	4.2	N. 86°W.	8.7	N. 82°W.	9.4	N. 83°W.	9.9	N. 79°W.	10.8	N. 74°W.	13.6	N. 68°W.	14.5	N. 61°W.	17.9	N. 43°W.	19.7
WNW	4.8	N. 63°W.	8.5	N. 61°W.	9.5	N. 63°W.	11.5	N. 60°W.	10.3	N. 57°W.	14.0	N. 47°W.	15.8	N. 35°W.	18.0	N. 48°W.	18.8
NW	3.9	N. 40°W.	7.5	N. 43°W.	8.5	N. 39°W.	12.3	N. 42°W.	12.5	N. 36°W.	14.3	N. 35°W.	16.2	N. 33°W.	17.4	N. 49°W.	21.6
NNW	3.5	N. 30°W.	6.6	N. 31°W.	7.5	N. 37°W.	7.7	N. 30°W.	8.5	N. 31°W.	10.7	N. 31°W.	15.2	N. 34°W.	16.5	N. 45°W.	17.0

## SUMMER

N	1.7	N. 6°E	4.4	N. 5°E	4.7	N. 3°E	5.2	N. 1°W	5.4	N. 17°W	7.3	N. 35°W	7.8	N. 29°W	10.4	N. 37°W	11.7
NNE	2.1	N. 21°E	5.2	N. 25°E	5.5	N. 21°E	5.3	N. 10°E	5.0	N. 6°W	4.9	N. 47°W	5.8	N. 30°W	7.6	N. 49°W	8.4
NE	2.0	N. 44°E	5.3	N. 46°E	5.4	N. 33°E	5.4	N. 32°E	5.0	N. 8°E	6.3	N. 5°W	7.9	N. 13°W	9.7	N. 35°W	10.9
ENE	2.3	N. 73°E	5.2	N. 70°E	5.8	N. 69°E	5.8	N. 60°E	5.6	N. 44°E	5.8	N. 6°W	4.3	N. 22°W	7.3	N. 22°W	9.6
E	1.9	S. 86°E	4.9	S. 77°E	4.4	S. 62°E	4.0	S. 69°E	4.4	N. 21°E	5.0	N. 24°E	5.8	N. 84°W	5.2	N. 67°W	5.8
ESE	1.6	S. 76°E	3.2	S. 73°E	3.3	S. 67°E	3.6	S. 68°E	3.9	N. 31°W	5.5	N. 56°W	5.2	N. 31°W	6.6	N. 69°W	5.8
SE	1.9	S. 27°E	4.1	S. 24°E	4.4	S. 18°E	4.1	S. 9°E	4.1	S. 27°W	3.6	N. 69°W	5.5	N. 69°W	7.0	N. 76°W	7.9
SSE	2.1	S. 7°E	5.2	S. 1°W	5.4	S. 10°W	4.9	S. 25°W	4.7	S. 47°W	5.6	N. 25°W	7.1	N. 72°W	7.6	N. 75°W	8.4
S	2.3	S. 11°W	5.4	S. 18°W	5.9	S. 16°W	5.7	S. 40°W	5.6	S. 61°W	6.2	S. 76°W	7.6	S. 83°W	8.3	S. 87°W	8.5
SSW	2.4	S. 47°W	7.0	S. 64°W	7.7	S. 60°W	7.1	S. 63°W	7.4	S. 86°W	9.5	N. 85°W	10.9	N. 73°W	11.4	N. 54°W	11.9
SW	2.3	S. 62°W	6.5	S. 68°W	7.6	S. 75°W	8.1	S. 81°W	8.5	W	10.0	W	10.8	N. 65°W	11.7	N. 66°W	12.8
WSW	2.5	S. 78°W	6.4	S. 83°W	7.0	S. 88°W	7.9	W	8.3	N. 81°W	9.8	N. 64°W	11.8	N. 72°W	12.9	N. 63°W	13.2
W	3.3	N. 85°W	7.5	N. 85°W	8.7	N. 84°W	8.6	N. 85°W	9.1	N. 74°W	10.1	N. 76°W	12.1	N. 76°W	12.9	N. 71°W	14.2
WNW	2.4	N. 61°W	6.2	N. 63°W	7.2	N. 66°W	7.1	N. 65°W	7.2	N. 70°W	8.5	N. 65°W	10.7	N. 59°W	12.4	N. 60°W	14.9
NW	3.0	N. 42°W	6.1	N. 38°W	6.5	N. 39°W	6.6	N. 45°W	7.5	N. 35°W	10.9	N. 52°W	13.7	N. 53°W	15.6	N. 38°W	17.3
NNW	2.6	N. 19°W	5.5	N. 23°W	6.4	N. 23°W	6.6	N. 28°W	6.7	N. 44°W	9.1	N. 50°W	10.7	N. 69°W	11.7	N. 61°W	14.0

## AUTUMN

N	3.0	N. 7°E	6.4	N. 5°E	6.9	N. 2°W	7.1	N. 14°W	7.9	N. 17°W	10.7	N. 23°W	13.5	N. 11°W	15.8	N. 24°E	16.8
NNE	2.3	N. 27°E	5.4	N. 33°E	6.1	N. 18°E	5.5	N. 10°E	4.8	N. 45°W	7.1	N. 40°W	8.1	N. 43°W	10.6	N. 27°W	13.1
NE	2.3	N. 50°E	6.2	N. 78°E	6.3	N. 75°E	6.6	N. 74°E	7.2	S. 45°W	6.5	S. 48°W	9.3	S. 68°W	10.3	S	11.9
ENE	1.8	N. 68°E	5.1	N. 65°E	4.8	N. 62°E	4.3	N. 46°E	4.3	N. 23°E	6.5	N	8.0	N. 7°W	9.4	N. 42°W	10.8
E	2.1	S. 88°E	5.0	S. 76°E	5.0	S. 76°E	5.4	S. 67°E	4.7	N. 63°W	5.3	N. 73°W	6.7	N. 71°W	9.6	N. 53°W	9.9
ESE	1.9	S. 52°E	6.6	S. 31°E	7.9	S. 14°E	8.1	S. 3°E	8.3	S. 55°W	9.3	S. 78°W	8.4	N. 88°W	9.1	S. 60°W	10.0
SE	2.3	S. 24°E	6.8	S. 16°E	7.4	S. 5°E	7.4	S. 3°W	7.6	S. 52°W	8.7	S. 57°W	11.3	S. 64°W	12.6	S. 53°W	12.7
SSE	2.5	S. 5°E	6.8	S. 6°W	8.0	S. 17°W	8.0	S. 40°W	7.8	S. 54°W	9.9	S. 74°W	13.2	S. 76°W	15.7	N. 77°W	17.4
S	3.2	S. 14°W	7.1	S. 25°W	7.2	S. 26°W	8.4	S. 30°W	8.4	S. 49°W	9.9	S. 69°W	11.0	S. 77°W	12.9	N. 82°W	14.4
SSW	2.6	S. 44°W	8.0	S. 53°W	9.3	S. 58°W	10.1	S. 63°W	10.8	S. 77°W	12.0	S. 89°W	13.6	S. 89°W	15.9	S. 82°W	16.1
SW	3.0	S. 59°W	8.5	S. 66°W	10.1	S. 72°W	11.0	S. 77°W	11.4	S. 88°W	13.3	S. 89°W	14.8	S. 86°W	15.9	W	16.9
WSW	3.0	S. 74°W	8.3	S. 78°W	9.4	S. 72°W	9.9	S. 77°W	10.0	N. 88°W	13.7	N. 76°W	14.4	N. 64°W	15.2	N. 38°W	15.9
W	3.1	N. 87°W	7.9	N. 86°W	9.9	N. 86°W	10.1	N. 82°W	10.8	N. 70°W	11.5	N. 60°W	12.0	N. 56°W	13.5	N. 50°W	14.6
WNW	3.2	N. 60°W	7.0	N. 58°W	8.4	N. 53°W	8.5	N. 53°W	9.0	N. 54°W	12.2	N. 51°W	13.9	N. 48°W	16.9	N. 6°W	17.3
NW	3.4	N. 42°W	7.5	N. 43°W	8.8	N. 45°W	11.6	N. 48°W	12.7	N. 58°W	15.2	N. 38°W	16.9	N. 66°W	20.2	N	21.1
NNW	2.8	N. 23°W	5.6	N. 27°W	6.1	N. 31°W	7.4	N. 39°W	8.4	N. 30°W	11.8	N. 46°W	12.6	N. 45°W	15.5	N. 45°W	16.6

## WINTER

N	2.4	N. 4°E	5.4	N. 1°W	5.7	N. 9°W	5.5	N. 21°W	6.8	N. 31°W	12.6	N. 37°W	17.0	N. 42°W	23.0	N. 67°W	28.2
NNE	2.9	N. 45°E	6.0	N. 50°E	7.0	N. 41°E	5.7	N. 37°E	5.6	N. 27°W	7.6	N. 41°W	12.9	N. 34°W	17.4	N. 46°W	22.3
NE	3.5	N. 45°E	6.6	N. 58°E	7.1	N. 58°E	7.2	N. 67°E	7.0	N. 7°E	7.8	N. 4°E	7.9	N. 33°W	10.2	N	12.6
ENE	2.4	N. 78°E	5.6	S. 89°E	5.5	S. 68°E	4.9	S. 21°E	5.9	W	6.1	N. 45°W	7.8	N	12.3	N	14.2
E	3.0	S. 74°E	6.9	S. 67°E	9.2	S. 65°E	8.3	S. 51°E	7.1	S. 70°W	5.6	N. 83°W	10.6	N. 88°W	14.6	S. 82°W	18.5
ESE	2.3	S. 67°E	5.9	S. 59°E	6.6	S. 47°E	7.4	S. 45°E	6.8	S. 61°W	6.8	S. 56°W	10.0	S. 36°W	13.2	S. 55°W	15.9
SE	2.9	S. 27°E	6.3	S. 7°E	10.3	S. 27°W	10.4	S. 36°W	9.9	S. 64°W	11.0	S. 83°W	14.7	S. 74°W	19.2	N	20.8
SSE	3.7	S. 7°E	9.2	S. 13°W	12.2	S. 24°W	13.1	S. 37°W	13.2	S. 73°W	13.2	N. 87°W	15.2	N. 82°W	17.5	N. 67°W	19.0
S	3.2	S. 21°W	8.4	S. 37°W	11.3	S. 50°W	12.9	S. 60°W	14.5	S. 86°W	14.8	N. 86°W	19.2	W	24.1	N. 85°W	26.3
SSW	3.1	S. 41°W	8.6	S. 67°W	10.8	S. 63°W	13.1	S. 67°W	13.2	S. 76°W	14.6	W	17.7	N. 81°W	22.7	N. 78°W	25.1
SW	3.4	S. 62°W	11.6	S. 74°W	12.0	S. 82°W	11.6	W	12.9	N. 75°W	12.7	N. 76°W	16.7	N. 67°W	20.6	N. 63°W	23.2
WSW	3.6	S. 78°W	8.3	S. 88°W	10.5	N. 83°W	11.5	N. 74°W	11.8	N. 79°W	11.9	N. 69°W	17.9	N. 68°W	28.0	N. 45°W	31.1
W	4.4	N. 84°W	9.5	N. 80°W	11.7	N. 73°W	14.4	N. 76°W	14.8	N. 68°W	21.9	N. 71°W	25.5	N. 59°W	20.8	N	30.2
WNW	4.8	N. 62°W	9.6	N. 60°W	11.9	N. 58°W	13.2	N. 58°W	14.4	N. 67°W	17.8	N. 10°W	21.5	N	23.7	N	23.9
NW	3.2	N. 44°W	6.9	N. 45°W	8.8	N. 46°W	9.6	N. 45°W	10.5	N. 52°W	14.9	N. 41°W	18.9	N. 39°W	23.2	N. 36°W	26.2
NNW	3.0	N. 27°W	6.3	N. 19°W	7.0	N. 29°W	9.4	N. 31°W	10.8	N. 43°W	15.9	N. 43°W	20.8	N. 45°W	26.7	N. 37°W	28.4

## ANNUAL

N	2.3	N. 8° E.	5.2	N. 1° E.	5.6	N. 5° W.	5.9	N. 13° W.	6.2	N. 20° W.	8.7	N. 28° W.	10.9	N. 45° W.	13.5	N. 40° W.	16.2
NNE	2.6	N. 27° E.	5.6	N. 32° E.	5.8	N. 22° E.	5.9	N. 14° E.	5.8	N. 19° W.	6.5	N. 37° W.	9.1	N. 40° W.	11.5	N. 43° W.	13.4
NE	2.8	N. 46° E.	6.5	N. 50° E.	7.0	N. 32° E.	7.0	N. 46° E.	7.1	N. 10° E.	7.5	N. 12° W.	8.9	N. 34° W.	11.1	N. 37° W.	12.7
ENE	2.4	N. 70° E.	6.6	N. 74° E.	5.9	N. 72° E.	5.7	N. 64° E.	5.9	N. 21° E.	6.6	N. 14° W.	7.1	N. 7° W.	9.0	N. 22° W.	10.5
E	2.6	S. 84° E.	5.6	S. 75° E.	6.2	S. 65° E.	6.0	S. 60° E.	5.8	N. 45° E.	5.7	S. 88° W.	6.6	N. 75° W.	8.0	N. 87° W.	9.8
ESE	2.2	S. 65° E.	5.9	S. 51° E.	6.1	S. 39° E.	6.3	S. 28° E.	6.4	S. 69° W.	7.0	N. 81° W.	7.2	S. 89° W.	8.2	S. 87° W.	8.7
SE	2.6	S. 30° E.	5.7	S. 25° E.	6.6	S. 14° E.	6.9	S. 11° E.	6.8	S. 60° W.	7.7	S. 71° W.	9.7	S. 89° W.	11.1	S. 88° W.	12.6
SSE	3.1	S. 9° E.	7.6	S. 3° W.	8.8	S. 13° W.	8.6	S. 30° W.	8.7	S. 62° W.	9.3	S. 69° W.	11.1	S. 86° W.	12.7	N. 77° W.	14.0
S	3.1	S. 19° W.	7.4	S. 27° W.	9.2	S. 33° W.	9.8	S. 44° W.	10.2	S. 66° W.	10.1	S. 76° W.	12.5	S. 85° W.	14.1	N. 84° W.	15.3
SSW	3.1	S. 42° W.	8.5	S. 51° W.	10.0	S. 57° W.	10.9	S. 62° W.	11.6	S. 78° W.	12.3	W	14.6	N. 80° W.	16.9	N. 75° W.	17.8
SW	3.0	S. 60° W.	8.2	S. 67° W.	9.4	S. 69° W.	10.0	S. 72° W.	10.6	N. 85° W.	11.6	W	13.3	N. 87° W.	14.8	N. 83° W.	16.4
WSW	3.3	S. 73° W.	8.6	S. 78° W.	9.4	S. 85° W.	10.3	S. 84° W.	10.4	N. 84° W.	12.9	N. 72° W.	15.3	N. 66° W.	16.6	N. 44° W.	17.5
W	3.7	N. 86° W.	7.8	N. 84° W.	9.6	N. 81° W.	10.3	N. 81° W.	10.9	N. 71° W.	12.8	N. 71° W.	15.7	N. 63° W.	17.7	N. 56° W.	19.1
WNW	4.2	N. 62° W.	8.3	N. 62° W.	9.2	N. 60° W.	9.2	N. 60° W.	9.5	N. 57° W.	12.7	N. 51° W.	15.7	N. 50° W.	17.7	N. 46° W.	19.1
NW	3.4	N. 43° W.	6.9	N. 43° W.	8.9	N. 46° W.	8.9	N. 47° W.	9.0	N. 51° W.	12.6	N. 51° W.	15.5	N. 46° W.	17.2	N. 42° W.	21.1
NNW	3.0	N. 23° W.	5.8	N. 25° W.	6.6	N. 29° W.	7.4	N. 32° W.	8.2	N. 35° W.	11.1	N. 43° W.	14.0	N. 56° W.	16.7	N. 54° W.	17.9

In Table 6 is given the percentage frequency of north and south components at 3,000 and 4,000 meters under differing conditions of wind direction at the surface. Here we find that with a north component at the surface the northerly influence persists 79 per cent of the time to 3,000 meters, and 80 per cent at 4,000 meters. With a south surface component the southerly influence continues at 3,000 meters in 39 per cent of all cases and at 4,000 meters in 33 per cent of all cases. With a west surface wind a north component prevails at 3,000 meters in 69 per cent of all times and at 4,000 meters the same percentage. The south component for west surface directions is noted 14 per cent of the time at 3,000 meters and 7 per cent at 4,000 meters. With west surface winds a due west direction may be expected in 17 per cent of all cases at 3,000 meters and 24 per cent at 4,000 meters. When all observations are considered, it is found that at 3,000 and 4,000 meters due west winds occur 19 per cent of the time, a north component 55 and 56 per cent, respectively, and a south component 26 and 25 per cent.

Table 7 contains a summary of resultant winds. A comparison of these figures with those in Table 4 is of interest. There is little difference in the directions shown, but the resultant speeds are decidedly lower than the average speeds at all levels, owing to the considerable number of times that east component winds, or at any rate winds at an appreciable angle from west to northwest (the resultant direction) occur, as indicated in Table 3. This difference in speeds diminishes with height, as the frequency of west-component winds increases.

TABLE 6.—Annual percentage frequency of north and south components in winds at 3,000 and 4,000 meters, with different surface directions

Direction at earth's surface	Number of observations	North component	South component	Due west
At 3,000 meters:				
E. to WSW.....	513	38	39	23
W.....	79	69	14	17
WNW. to ENE.....	323	79	9	19
All directions.....	915	55	26	12
At 4,000 meters:				
E. to WSW.....	350	45	33	24
W.....	45	69	7	24
WNW. to ENE.....	248	80	11	9
All directions.....	643	56	25	19

TABLE 7.—Free-air resultant winds (m. p. s.) at Lansing, Mich.

Altitude	Spring		Summer		Autumn		Winter		Annual	
	Direction	Vel.	Direction	Vel.	Direction	Vel.	Direction	Vel.	Direction	Vel.
m.		m. p.		m. p.		m. p.		m. p.		m. p.
Surface.....	S. 76°W.	0.9	S. 85°W.	0.2	S. 69°W.	1.1	S. 75°W.	1.3	S. 76°W.	0.9
250.....	S. 73°W.	2.6	N. 88°W.	2.2	S. 74°W.	3.4	S. 76°W.	3.5	S. 70°W.	2.9
500.....	S. 73°W.	3.0	N. 84°W.	2.6	S. 73°W.	3.4	S. 82°W.	5.2	S. 81°W.	3.6
750.....	S. 81°W.	3.5	N. 85°W.	2.8	S. 81°W.	4.7	S. 85°W.	6.1	S. 86°W.	4.3
1,000.....	S. 86°W.	4.2	N. 79°W.	3.0	S. 81°W.	5.7	N. 88°W.	7.8	W.....	5.2
1,500.....	W.....	5.7	N. 75°W.	3.9	W.....	7.0	N. 79°W.	9.2	N. 84°W.	6.4
2,000.....	N. 83°W.	6.6	N. 71°W.	4.9	N. 88°W.	7.5	N. 78°W.	10.3	N. 80°W.	7.3
2,500.....	N. 77°W.	7.2	N. 69°W.	5.8	N. 83°W.	8.4	N. 74°W.	12.0	N. 76°W.	8.4
3,000.....	N. 70°W.	7.8	N. 65°W.	6.0	N. 83°W.	9.0	N. 71°W.	13.6	N. 72°W.	9.2
3,500.....	N. 62°W.	7.9	N. 61°W.	5.6	N. 77°W.	9.6	N. 66°W.	13.6	N. 67°W.	10.0
4,000.....	N. 67°W.	8.7	N. 62°W.	6.9	N. 66°W.	9.9	N. 66°W.	14.3	N. 69°W.	10.7
4,500.....	N. 63°W.	9.6	N. 60°W.	7.5	N. 79°W.	9.6	N. 63°W.	16.2	N. 66°W.	10.7
5,000.....	N. 62°W.	9.4	N. 58°W.	7.5	N. 77°W.	9.1	N. 55°W.	15.9	N. 63°W.	10.5
6,000.....	N. 61°W.	9.3	N. 58°W.	7.4	N. 70°W.	9.3	N. 56°W.	16.7	N. 61°W.	10.7

## RECORDS OF TOTAL SOLAR RADIATION INTENSITY, AND THEIR RELATION TO DAYLIGHT INTENSITY<sup>1</sup>—A CORRECTION

By HERBERT H. KIMBALL

[Weather Bureau, Washington, February 12, 1925]

Dr. C. G. Abbot has kindly called my attention to the fact that footnote 14 on page 475 of the above-named paper does not apply to Mount Wilson. The data for Mount Wilson given in Table 1 on the same page were obtained from the Astronomical Journal for March 14, 1914, 28 : 133, and are based on bolometric measurements made on September 22 and 24, 1913. With respect to these measurements Dr. Abbot states:

At that time the dust from Mount Katmai was still affecting the transparency and the larger part of the observations were made in the afternoon when the mountain is overlaid with haze which comes up with the sea breeze. The work was done employing the same quartz lens which was used on Mount Whitney. It is likely that these results and those for Mount Whitney, compared to others in your table, indicate too great brightness for the sky for this and three other reasons: First, the lens had a considerable number of striae which doubtless introduced some stray sunlight; in the second place, a thin quartz lens would be apt to transmit some radiation proper to the sky itself which during the afternoon might be warmed sufficiently to produce a positive deflection; and in the third place, the quartz lens is transparent to the extreme ultra-violet which would be cut off in the pyranometer experiments as also in the bolometric ones of 1905 and 1906 when glass was inserted. . . . If, owing to the circumstances I have related, it were recognized that some increase of the ratio factor for Mount Whitney

and also for Mount Wilson is desirable, I believe the system [of ratios in Table 1] would be nearer the truth.

Reference to Figure 1 and Table 2, MONTHLY WEATHER REVIEW for November, 1924, 52 : 528, 529, shows that the means of pyrheliometric measurements of direct solar radiation made at Warsaw, Poland; Simla, India; Paris, France; Mount Weather, Va.; Kew Observatory, England; Madison, Wis.; and Santa Fe, N. Mex., give intensities in September, 1913, that are about 5 per cent less than the average for September under normal atmospheric conditions.

The probability that Doctor Abbot is correct in his statement is further strengthened by a consideration of the sky-brightness measurements made on Mount Wilson in 1905 and 1906. (See Annals of the Astrophysical Observatory, vol. 2, pp. 146-152.) These give for the ratios of Table 1, above quoted, for solar zenith distance 25°, 17.4, and for solar zenith distance 51.5°, 8.4. Therefore my statement on page 475 that the measurements for Hump Mountain "do not seem to be in accord with other measurements, since they show too little sky radiation" does not seem to be in accord with the facts as now set forth and should be stricken out.

<sup>1</sup> MO. WEATHER REV., October, 1924, 52:473.